NASA Flight Proven Practices and Techniques

Reliability Preferred Practices for Design and Test

NASA Technical Memorandum 4322

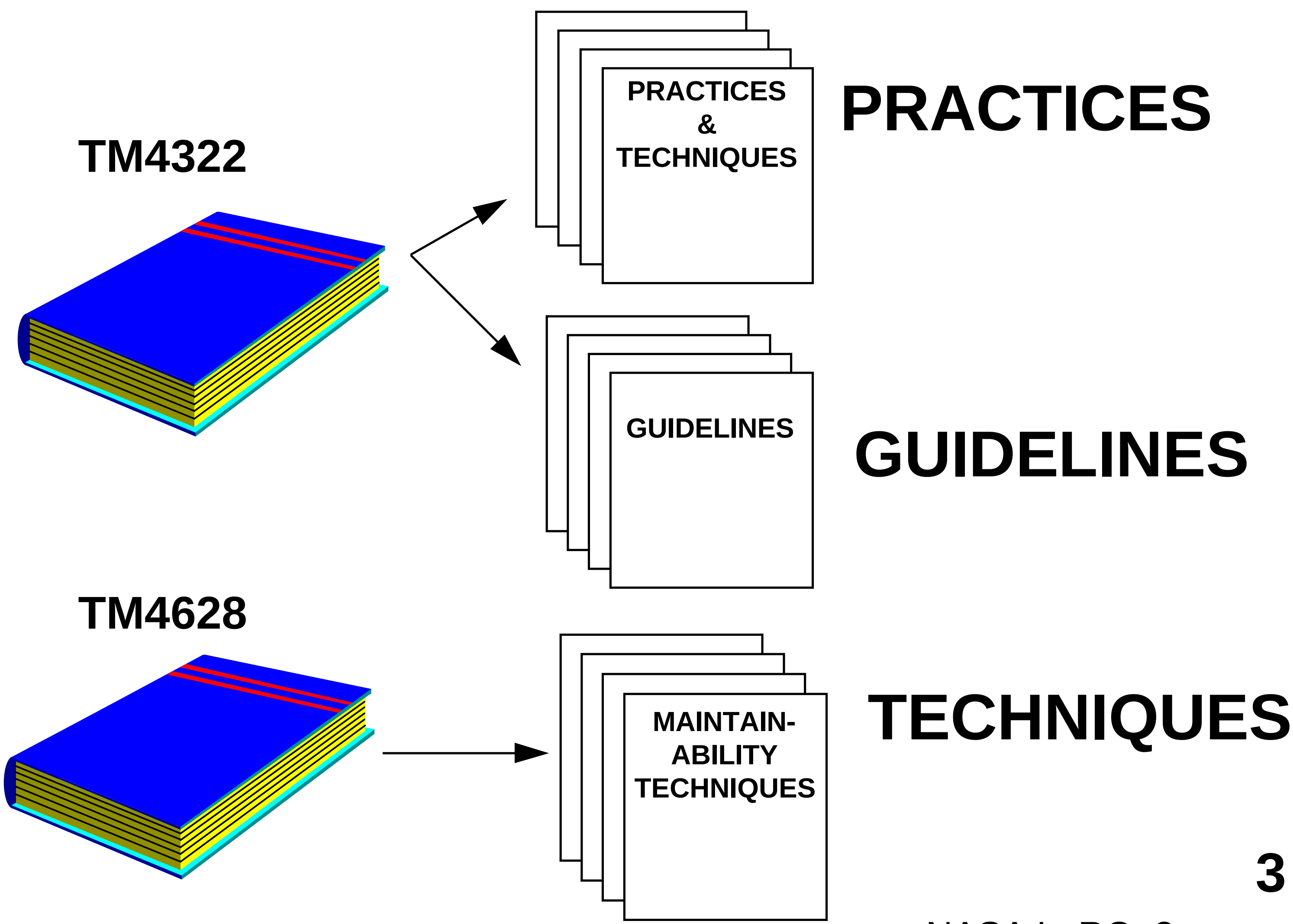
Recommended Techniques for Effective Maintenance

NASA Technical Memorandum 4628

PURPOSE OF NASA TM-4322/4628

- **These manuals summarizes the best Reliability, Availability, Maintainability and Safety (RAMS) experience available (as reflected in in design, test and/or operational advice) for flight proven techniques (practices) and generally recommended procedures (guidelines).**
- **Promotes systematic approach to RAMS discipline.**
- **Reflects engineering principles to support current and future civil space programs.**
- **Practices represent the "best technical advice" from both NASA and industry.**

ORGANIZATION OF MANUALS



How Can These Methods Be Used?

- Provide the project manager a consistent technical basis on which to evaluate the technical risks in his project at specific milestones.
- Provide important information so that the design engineer can gain insight about the requirements, processes and procedures that were used in the past on similar designs and that improved these methods.
- Provide the assurance specialist flight with proven methods from which he can evaluate the project design, test and operation procedures for achieving high RAMS performance.

USE THESE PRACTICES FOR DESIGN, TEST AND OPERATIONAL REVIEWS

Philosophy of NASA TM-4322/4628

- RAMS efforts must focus on methods that reduce frequency of failure.
- These methods must be controlled through the application of conservative engineering principles.
- RAMS contributes to system development by assuring that:
  - Operating environments are well defined and independently verified.
  - Criteria drive a conservative approach.
  - Weaknesses evident by test or operations are identified and tracked.
  - Quick maintenance of systems.

Organization of TM4322

I. Manual Overview / Introduction

II. RAMS Practices -- sorted by:

- **1. Design Factors -- 1.1 Environmental Considerations**
- **2. Design Factors -- 1.2 Engineering Design**
- **3. Design Factors -- 1.3 Analytical Procedures**
- **4. Test Elements (procedures)**

III. Design Guidelines/ Handbooks (same design factors and test elements).

Organization of TM4628

- I. Program Overview.
- II. Design Techniques for Effective Maintenance.
  - Program Management.
  - Design Factors and Engineering.
  - Analysis and Test.
  - Operations and Operational Considerations.

Benefits of Manuals

- To aid in assessing current RAMS techniques.
- To promote proactive technical interchange
  - Between management, engineers, technicians, and students
  - With focus on trade-offs and their impact on design, testing, maintenance and logistics requirements
- To underscore the urgent need for mature attitudes on RAMS methods.

Purpose of Manual--to restate:

- To summarize RAMS experience from NASA and industry.
- To promote systematic approach to RAMS discipline.
- To record flight proven practices that support current and future aeronautic/space programs.
- To capture maintainability techniques used by NASA.

Fundamental RAMS Elements

- Understand factors imposed on flight hardware by its mission environment.
- Controlling these factors through selection of conservative design criteria
- Performing appropriate analysis to identify and track operational needs.
- Carefully select operational alternatives to provide the necessary function should failure occur.

TM 4322 Reliability Practices

- **A practice has been proven by mission success.**
- **Supplement No. 2 contains practices on:**
  - **Environmental Considerations**
  - **Engineering Design Methods**
  - **Analytical Procedures**
  - **Test Considerations & Procedures**
- **A typical RAMS practice (Environmental Factors) is illustrated.**

Practice Example
Environmental Factors

- **Practice (PD-EC-1101):** Identify equipment operating conditions encountered during life cycle.
- **Benefits:** Assures that adequate environmental strength is incorporated into design to ensure reliability.
- **Programs That Certified Usage:** Advanced Communications Technology Satellite, space experiments, launch vehicles, space power systems, and Space Station.
- **Center to Contact for More Information:** Lewis Research Center

Environmental Factors

Implementation Method

- To ensure a reliable oriented design, determine the needed environment resistance of the equipment.
- A life-cycle environment profile is a forecast of events and associated environmental conditions that a product experiences from manufacturing to retirement.

Environmental Factors

Implementation Method (Cont.)

Eight factors that should be taken into account:

1. **Hardware configuration.**
2. **Environment(s) that will be encountered.**
3. **Platform/hardware interfaces.**
4. **Interfaces with other equipment.**
5. **Absolute and relative duration of exposure phase.**
6. **Probability environmental condition(s) will occur.**
7. **Geographical locations.**
8. **Any other information that will identify environment.**

Environmental Factors

Implementation Method (Cont.)

- **Steps in developing a life-cycle environmental profile:**
  - **1. Describe anticipated events from final factory acceptance through removal from inventory.**
  - **2. Identify significant natural and induced environments for each event.**
  - **3. Describe environmental and stress conditions.**

Environmental Factors

Technical Rationale

- Equipment reliability is dependent on operating conditions during life-cycle.
- Environmental factors that strongly influence equipment reliability are listed in the practice.
- Concurrent environments may be more detrimental to reliability then the effects of a single environment.

Environmental Factors

<u>Technical Rationale</u> (Cont.)

- **Each environmental factor that is present requires a determination of impact on the operational and reliability characteristics of the part or materials used in the equipment.**
- **The practice provides reliability considerations for pairs of environmental factors.**
- **The principle effects of typical environments on system parts and materials is given in the practice.**

Environmental Factors

Impact of Nonpractice

- **Failure to perform a detailed life-cycle environment profile can lead to overlooking environmental factors whose effect are critical to equipment reliability.**
- **If these factors are not included in the environmental design criteria and test program, environmental-induced failures may occur during mission operations.**

TM4322 - Reliability Guidelines

- A guideline represents the best design, test and/or operational advise that is available.
- Supplement No. 2 contains guidelines on:
  - Engineering Design Procedures
  - Analytical Procedures
  - Test Considerations & Procedures
- A typical reliability guideline, Earth Orbit Environmental Heating, is shown in the ADDITIONAL INFORMATION section.

TM4628 - Maintainability Techniques

- **These maintainability manual represent a collection of recommended techniques from the various NASA centers, the Jet Propulsion Laboratory (JPL) and NASA contractors.**
- **These techniques cover program management, design, analysis/test and operations.**

TM4628 - Maintainability Techniques Format

- **Technique: a brief statement defining the design practice and how it is used.**
- **Benefit: Technical improvement and impact of use.**
- **Key Words: Utilized for document search purposes.**
- **Application Experience: Identifies what programs the technique was used on.**
- **Center to Contact: contact information.**
- **Technical Rationale: technical justification for using the practice.**
- **Technical Description: A discussion of the application of the technique.**
- **References: Additional information sources.**

TM4628 - Maintainability Techniques Example DF-2, *False Alarm Mitigation Techniques*.

- **Technique: Minimize the occurrence and effects of BIT [Built-In Test] false alarms.**
- **Benefits: Increased system availability. Faster diagnosis. The ability to isolate faults to determine what has failed.**
- **Technical rationale: Testability must be treated with the same level of importance as other design disciplines....**

TM4628 - Maintainability Techniques Example DF-2, *False Alarm Mitigation Techniques* *(continued)*.

- **Technical Discussion: BIT should distinguish among anomalies that are: (1) actual failures, (2) must be tolerated due to adverse operating conditions and (3) anomalies which do not affect operation.**
- **Voting systems allow for multiple analysis of an event or multiple sensors to evaluate sensor failure.**
- **Recording of BIT data over time to determine refine sensor data to more precisely evaluate critical alarms.**
- **Use decentralized architecture placing BIT on a replaceable unit.**
- **Use high quality components for BIT implementation.**

CONCLUSION: How Can These Practices, Guidelines and Techniques Be Used?

USE THESE PRACTICES AND GUIDELINES TO:

- **Provide the project manager a consistent technical basis on which to evaluate the technical risks in his project at specific milestones.**
- **Provide important information so that the design engineer can gain insight about the requirements, processes and procedures that were used in the past on similar designs and that improved these designs.**
- **Provide the assurance specialist flight proven practices from which he can evaluate the project design, test and operation procedures for achieving high reliability.**

END

ADDITIONAL INFORMATION

Guideline Example

Earth Orbit Environmental Heating

- **Guideline (GD-AP-2301):** Use currently accepted values for solar constant, albedo, and Earth radiation when calculating heat balance of Earth orbiters. This guideline provides heating rate for blackbody case without considering spectral effects or collimation.
- **Benefit:** Accurately predicts thermal environment of orbiting devices.
- **Center to Contact for More Information:** Goddard Space Flight Center
- **Technical Information:** The constraints and factors necessary for these calculations are given in the guideline. A brief explanation of the formulas used in the guideline is as follows:

Equivalent Sink Technique

- **The equivalent sink technique can be used by replacing all surrounding surface radiant interchanges and the absorbed Solar and Earth energies to node i with a single radiation coupling to single node at temperature T sink.**
- **The Guideline gives the following equation for performing the technique:**

$$\sigma T_s^{\,4} = \frac{Q_{s+A} + Q_{IR} + \sum_{n-1}^{k} \mathcal{F} A_{i-n} \sigma T_n^{\,4}}{\varepsilon_i A_i}$$

Equivalent Sink Technique (Cont.)

- **Where:**
  - Q_{S+A} = absorbed solar & albedo energy
  - Q_{IR} = absorbed earth IR energy
  - Q_{I} = internal power dissipation
  - σ = Stefan-Boltzman constant
  - FA_{i-n} = Radiant interchange factor
  - A_i = Area of node i
  - ε_i = emissivity of node i
  - T_s = sink temperature
  - T_n = temperature at node n
- **The guideline explains how to use this equation.**

Technical Rationale

- **Thermal analysis of an earth orbiting spacecraft requires the accounting of incident thermal energy from all external sources.**
- **The most significant external sources of energy incident on the spacecraft are the sun, the thermal radiation of the earth, and the solar energy reflected from the earth (albedo)**
- **The modification of the energy incident on the spacecraft due to the earth-sun distance variation, and the accuracy of the measurements of the solar constant, are of sufficient magnitude to be important parameters in performing a thermal analysis.**

Impact of Nonpractice

- Not considering the variations in the environmental thermal effects as described in this guideline will result in an incomplete thermal analysis.
- The temperature variation of the spacecraft could be grossly underestimated, thereby reducing its reliability.